

PATTERNS OF REFRIGERANT USE RESULTING FROM REGULATIONS DESIGNED TO PROTECT THE ENVIRONMENT

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Abstract: The HVAC&R industry is changing rapidly. This is response to the environmental challenges of ozone depletion and global warming. The contractor working in this industry faces tough competition and increasing technical difficulties. These difficulties can be turned into a competitive advantage if the contractor understands the source of the difficulties. This paper explores some of the industry wide problems and solutions. The new refrigerants are many and are covered by venting, recycling and reclamation rules. They are very stable refrigerants and are generally used with ester lubricants. Understanding some of these issues will allow contractors to take advantage of the benefits brought about by some of these technological changes.

INTRODUCTION

The chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) have been used as refrigerants for over 30 years. These chlorine containing substances have been shown to destroy stratospheric ozone. This has led to the signing of the Montreal Protocol in 1987 and to the 1990 Clean air Act which require the phaseout of production of the CFCs by the end of 1995. The last seven years have seen the introduction of several alternative refrigerants that contain no chlorine and do not deplete the ozone layer.

The purpose of this paper is to review the status of the refrigeration and air conditioning practice today. During the last 10 years, the industry has changed very dramatically. Ten years ago we had the CFCs and the industry was established and sleepy. The push to remove the chlorofluorocarbons was just beginning. At this point, the CFCs are gone. The hydrofluorocarbons (HFCs) are here. The main issues in the industry lie in the retrofit area and new equipment. Only a very few companies have stored CFCs for use in the near future. Understanding the business, therefore, means understanding retrofit and the use of HFCs in new equipment. The only exception is the continued use of R22 mainly in air

conditioning. These are only a few of the changes affecting the industry. From the point of view of the HVAC&R contractor, other important changes include the deregulation of utilities. This allows utilities to compete in servicing some equipment in the heating and cooling business. The new business climate is full of challenges. There is a need to develop a competitive advantage (7). This advantage can be a much better understanding of key issues in the industry.

Many consumers are now aware of the issues of ozone depletion and global warming. The worker in this industry should be able to explain to the consumer customer how the industry is addressing these issues. The ultimate customer wants to know that product is safe and does not harm the environment. In addition the product should be efficient so as to reduce operating costs. In the past the ultimate customers asked fewer questions. This new consumer awareness represents an opportunity for contractors and others to differentiate themselves from their competition. They can do this by becoming more able to discuss the issues and provide correct answers to the questions that arise in the course of using these new refrigerants.

RELATIONSHIP WITH OEMS AND REFRIGERANT MANUFACTURERS

From the standpoint of the air conditioning contractor or distributor, it is necessary to understand the situation of the refrigerant producers and original equipment manufacturers who are their suppliers. There are many refrigerants that can now serve the same application. All equipment manufacturers are faced with introducing many new equipment models. The contractor who understands some of the issues involved should be able to develop a better relationship with the equipment manufacturers. Such a contractor is better able to explain the reasons for the existence of new features on the new models and give good reasons and benefits for increasingly expensive service.

There are now four chemical major producers who are manufacturers of the new refrigerants. They have all made substantial investments in facilities to manufacture of these refrigerants. There are at least 27 refrigerant blends listed in ASHRAE Standard 34 (1). The key components of the HFC blends are R125, R32, R143a and R134a. Many are close substitutes for each other. There is confusion about the claims being made for the various products. It has become important to have a good relationship with your refrigerant supplier so that you the customer can have another good source of reliable advice on how to apply the new refrigerants. It is in the interest of these manufacturers to assist contractors in the introduction of these new products. There is definite need to disseminate key information to the field and to maintain two way communication. We will now discuss some of the key issues in the use of hydrofluorocarbons.

NEW REFRIGERANTS.

ASHRAE-34-1992 describes a shorthand way of naming refrigerants and classifies them according to their flammability and toxicity. The naming scheme uses numbers and can be broken into three categories. The first refers to single component refrigerants, the second to azeotropes and the last to zeotropes. An azeotrope is a mixture of refrigerants whose composition does not change as it is charged into or removed from a refrigeration system. A zeotrope is a mixture of refrigerants whose composition does change as it is charged into or removed from a refrigeration system. This change in composition is called fractionation. The properties of azeotropic and zeotropic refrigerants are very important and will be discussed in more detail later in this paper. For single compound refrigerants, the numbers refer to the number of fluorine, carbon and hydrogen atoms in the molecule and will not be discussed further here. Azeotropes are designated as R5xx while zeotropes are designated as R4xx where xx represents two digits. For a mixture containing the same components, there can be different proportions approved as different refrigerants. Thus there are three mixtures of R32, R125 and R134a approved as refrigerants. They are designated 407A, 407B and 407C.

Those refrigerants that are judged to have lower toxicity are classified in the A category. Those that are determined to have higher toxicity are classified in the B category. If the refrigerant shows no flame propagation according to ASTM-681, it is classified in flammability grouping 1. For lower flammability and higher flammability respectively the flammability categories are 2 and 3. Thus, from a safety standpoint the best overall classification for a refrigerant is A1. For zeotropic refrigerant blends, there are two compositions evaluated for safety. The first is for the as formulated composition. The second refers to the fractionated composition that results in the highest concentration of the flammable components or "worst case" fractionation. Thus AZ20 or R410A, R407A, R407B, R407C and R404A are zeotropes and are classified as A1/A1.

ASHRAE-34-1992 now recognizes ten azeotropes and 20 zeotropic refrigerants. This contrasts with 7 azeotropes and 1 non-azeotropic refrigerant recognized just four years ago. In addition there are numerous pure refrigerants. The need to understand the service implications of using azeotropes and blends is now critical. The composition of an azeotrope does not change as it is removed from a container. The composition of a zeotropic refrigerant does change as it removed from a container. This composition change is called fractionation. Fractionation will affect the performance of the system. Fractionation is more likely if the vapor phase is being removed from a container. Thus, charging of zeotropic refrigerants must be in the liquid phase. Most refrigerant manufacturers recommend charging any blend from the liquid phase. Warnings are usually printed on the refrigerant cylinder and carton instructing the user as to the proper orientation of the cylinder during charging. Furthermore, when zeotropic refrigerants are used in systems with accumulators, composition shifting can occur and can affect the performance of the system. Similarly where there has been significant loss of refrigerant from the vapor lines of an operating system, refrigerants can leak selectively and reduce the performance of the refrigerant. In this case it is better to remove the entire refrigerant charge when servicing and to replace it with new or reclaimed

refrigerant rather than "topping off" the depleted charge. For zeotropes, there is a change in temperature between the point at which the liquid first begins to evaporate and the point at which the evaporation is complete. This difference is called a temperature glide. For zeotropes with large glides, such as R407C with a glide of 8°F, there is a high level of fractionation. For zeotropes with low glides, there is almost no fractionation. For some zeotropes, such as R410A, these effects are so minimal as to almost not be a concern since the temperature glide is less than 0.3°F in conventional applications.

ANSI/ASHRAE 15-1994 (2) uses the classifications defined in ANSI/ASHRAE 34-1992 to develop, among other things, the amount of refrigerant allowable in a given space, that when exceeded requires a machine room. For example, for R134a, this amount is 60,000 ppm by volume. This number is determined by evaluating the acute toxicity, flammability, and oxygen deprivation limits of the refrigerant and selecting from these three parameters the lowest concentration in air (maximum exposure level) which may have an impact on public health or impair the ability of a person to escape in the event of a release of refrigerant in air. This standard provides values for some refrigerants as well as the methodology for arriving at values for a blend. ANSI/ASHRAE 15-1994 also provides information on pressure ratings of vessels and required pressure relief devices. Both of these standards are being revised as new refrigerants are brought forward by refrigerant producers.

VENTING, RECYCLING AND RECLAMATION

Section 608 of the Clean Air Act as of November 15, 1995 prohibits the venting of HFCs, HCFCs and CFCs. Individuals cannot knowingly vent them during service. The refrigerants must therefore be recovered, recycled, reclaimed or destroyed. The ARI has produced the Industry Recycling guideline IRG-2 (3) which provides definition of terms and describes the problems and solutions in the area of recycling and reclamation. Recovery is defined as simply removing a refrigerant from a system and storing it in a container. Recycling of a refrigerant is usually done in the field and

includes reduction of the level of contaminants such as moisture, acidity and particulate matter. Reclamation of a refrigerant requires the reprocessing of the used refrigerant to new product specifications as described in ARI Standard 700. A key guideline is that used refrigerants cannot be reused in another owner's equipment or resold unless it is shown to meet the purity requirements set down in ARI Standard 700.

Recycling and reclamation of single component and azeotropic refrigerants is much simpler than that of zeotropic refrigerants. For high glide zeotropes, recycling is problematic. This is because the composition must be determined before you can be sure of the performance that you will obtain the refrigerant. There are a few devices intended for determination of the composition of refrigerants in the field. Their use is not yet widespread. This reflects some practical difficulties. The first is that many of the devices are expensive. The second is that the reliability of the information provided by some of the devices may not be adequate for the intended use. The third is the ease of use and flexibility of the devices need to be improved. The situations encountered in the field are many and varied. Some devices are designed for a narrow set of circumstances. Nevertheless, progress is being made. Affordable field refrigerant analyzers will someday be a part of the toolkit of every good contractor. Until then, the practical solution is to send the used zeotrope back to the refrigerant producer for reclamation. Refrigerant manufacturers have set standards for acceptance of used refrigerants into their reclamation programs. Contractors who develop procedures that avoid the mixing of refrigerants in the field should find these programs easy to use. All refrigerants used in original manufacturer's equipment must meet quality specifications cited in ARI Standard 700. The next publication of Standard 700, expected in mid 1996, will contain many of the new refrigerants which have been commercialized in the last two to three years.

ALTERNATE TECHNOLOGIES.

With the coming of the new refrigerants, there has been a reexamination of the possibility of using technologies that are not based on fluorocarbons for air conditioning and refrigeration. In Europe, hydrocarbons are

being used in some domestic refrigerators. There is greater interest in desiccant cooling. Some systems have been designed for combined desiccant cooling and vapor compression. There is also renewed discussion of absorption. These and other alternative technologies are discussed in a 1994 AFEAS (Alternative Fluorocarbons environmental Acceptability Study) report (4). Most of these technologies have some merit but so far do not deliver performance and environmental benefits at a cost that is comparable to vapor compression.

HCFCs AND OZONE DEPLETION

The Montreal Protocol and the Clean Air Act are based on the fact that the chlorine containing refrigerants have been linked to the depletion of the stratospheric ozone layer. Starting in 1996, there is a cap on the production of HCFCs. The cap will be reduced in following years. By 2010, new equipment cannot be manufactured with R22. By January 1, 2020 the cap will be reduced by 99.5%. Ten years later all HCFC production will cease. However, HCFCs can still be used for servicing existing equipment to the year 2040.

As a result of these legislative actions, several refrigerant manufacturers have developed and introduced HFC alternatives for R22. The most prominent of these are R407C and R410A. These two products are distinctly different. They are both zeotropes. R407C has a glide of 8°F. By contrast the glide for R410A is at most 0.3°F. R407C can be used in existing equipment with the approval of the original equipment manufacturer or in new equipment. However, results of system tests with R407C have shown efficiency shortfalls of 5 to 10 % relative to R22. The vapor pressure of R410A is about 50% higher than that of R22. This means that new equipment must be designed for this refrigerant. The refrigerant provides the industry with the challenge of designing for higher pressures. It also provides the opportunity for taking advantage of the significantly greater efficiency of this refrigerant due to better heat transfer and the opportunity of designing physically smaller systems because of the higher capacity of R410A. System tests of this refrigerant have shown efficiency increases of about 5 % relative

to R22. Equipment manufacturers have met this challenge. There is at least one commercially available system using R410A with more to come. The challenge to contractors is to begin to understand the legislative and competitive forces driving this activity. In addition they must grasp the issues involved in living day to day with HFC refrigerants. This includes providing training and appropriate equipment for installers and service people.

GLOBAL WARMING

There is concern about global climate change caused by human activities. This concern is crystallized in the discussion about global warming of greenhouse gases. Refrigerants and carbon dioxide are examples of greenhouse gases. The contribution of all fluorocarbons used today and in the foreseeable future may only be a few percent of the total global warming. The chief contributor to global warming is carbon dioxide emitted from natural and human sources. Several governments and organizations, including the US Environmental Protection Agency, have issued policy statements supporting the reduction or halt in growth in the emissions of greenhouse gases by the year 2000.

This global warming contribution of a refrigerant can be broken into two factors. The direct global warming is caused by the release of the refrigerant into the atmosphere. The indirect global warming caused by refrigerants results from the burning of fossil fuels to generate the power required to operate the air conditioning and refrigeration machinery. The direct and indirect effect are both included in concept of total equivalent warming impacts or TEWI. Since TEWI is dependent on the efficiency of the system, it is difficult to assign hard and fast TEWI values. Nevertheless, general comparisons between refrigerants and, even more appropriately between refrigerants in systems can be made. A contractor needs to be familiar with the concept. It explains why it is important to avoid releasing HFCs to the atmosphere. It explains why it is advantageous to the environment to have higher efficiency.

HYDROCARBONS

One of the comparisons being made is that between hydrocarbons and hydrofluorocarbons. Hydrocarbons have lower direct global warming potential than do hydrofluorocarbons although the hydrocarbons are Volatile Organic Compounds (VOCs) producing ground level ozone which is a form of air pollution. Like the hydrofluorocarbons, they contain no chlorine and so have zero ozone depletion potentials. Some hydrocarbons can have good thermodynamic efficiency. A major problem is that hydrocarbons are flammable. This safety issue does not rule out hydrocarbons. Equipment can be designed to take account of this safety issue although many equipment manufacturers are concerned about their liability and system costs to meet safety requirements. For a similar higher cost, the equipment using hydrofluorocarbons can be made much more efficient and still not have the problem of flammability. It is true that for very small equipment using hermetic fractional horsepower compressors with very small charges, the safety hurdle that hydrocarbons face is somewhat smaller.

The other issue with regards to hydrocarbons concerns their use as retrofit refrigerants. In this case, the original equipment probably was not designed for use with flammable refrigerants. Contractors must not consider using hydrocarbons as retrofit fluids without first contacting the system equipment manufacturer. It must be remembered that most people regard air conditioning and refrigeration equipment as very safe and do not associate with them the need for precautions related to flammability.

RETROFIT

For the commercial refrigeration sector of the industry, retrofitting of supermarkets is a substantial part of the business. A store owner who retrofits with R22 containing interim blends finds some advantage in not having to switch to ester lubricants from mineral oils. Ester lubricants are synthetic materials as opposed to mineral oils which are petroleum based. In most cases this advantage is diminished since there is still need to switch from mineral oil to alkylbenzene oil. With this exception, there is no advantage to the interim solutions. The HFC refrigerants should therefore be considered when choosing retrofit

fluids. The choices are either R507 or R404A. Retrofitting procedures include changing of gaskets, leak checking of the system, flushing of the mineral oil with ester lubricant. It would be helpful if contractors would leak check the system before loading the new refrigerant into the system.

LUBRICANT ISSUES

The lubricants of choice are for the most part esters. A number of oil manufacturers and distributors now provide refrigeration grade ester oils. Equipment manufacturers should be consulted before using any new lubricant in a refrigeration system. Esters have been found to work fairly well with the hydrofluorocarbon refrigerants (6). These refrigerants have enough solubility in ester lubricants to provide good oil return under most circumstances. The oil return in a system is governed by the solubility of the refrigerant in the oil, the velocity of the refrigerant traveling through the system and the geometry of the system.

While esters are the main choice for use as lubricant for hydrofluorocarbons, some have been advocating the use of mineral oils for use with HFC refrigerants. The HFC refrigerants have minimal solubility in the mineral oils. However, it has been shown that in systems with enough refrigerant velocity, the mineral oil does return to the compressor. In addition some workers in this field have used additives in mineral oils to improve their dispersibility in HFC refrigerants. It has been reported that tests with this material have been successful. The systems that have been used are usually small systems such as domestic refrigerators. No major equipment manufacturing company has as yet adopted a mineral for use with HFC refrigerants.

In the past, the lubricity of the oil was enhanced by the presence of the presence of chlorine from breakdown products of the CFCs or the HCFCs. The chlorine is not present in HFCs. The HFCs are very stable and, therefore not the source of any lubricity enhancing breakdown products. The oil itself must provide the lubricity or additives must be used. In the past, experts in the air conditioning and refrigeration field preferred not to use additives. Lubricity additives are effective because they break down and chemically

interact with the metals in the system to provide in situ lubrication. This breaking down of the additives is in direct contradiction to the requirement for chemical stability in a refrigerant system but is required for the effectiveness of lubricity additives. This explains the previous reluctance to use additives. There has been much progress in this area but the search for additives that are effective, yet stable, continues.

The ester lubricants are generally stable. This is especially true when the system is dry and free of air. In the presence of moisture, hydrolysis can occur. This is the reaction of the ester with water to form an alcohol and an organic acid. The ester lubricants have been designed to reduce the extent of this reaction. Nevertheless, it is very important to keep the system dry. The presence of air will cause oxidation. Oxidation can, in the presence of water, then enhance hydrolysis. In addition, the normal reaction of organic fluids in a system that experiences hot spots will occur. In almost all cases, if the system is kept dry and free of air, there will be few if any problems.

This last question raises the issue of service practices. There was no problem leaving the mineral oils open to the air. This was because the mineral oil is saturated at 38 ppm moisture. The new ester lubricants are saturated at levels that can range 500 ppm to more than 1000 ppm. If left open for long periods, the ester will therefore absorb water. Water in a refrigeration system is bad news in general. In a system that uses ester lubricants, the potential for harm is enhanced because of the hydrolysis reaction. It was never good service practice to assemble a system without ensuring that the system was dry and free of air. In the future, adherence to such good and durable standards will constitute a competitive advantage for contractors.

We have discussed the issue of moisture in the lubricant. The HFC refrigerants also have a high water capacity. R410A is saturated at about 1200 ppm at room temperature. In a system with liquid and vapor, the vapor will contain a moisture level that is about 35 to 50 % that of the liquid. Thus the vapor is drier than the liquid. This is similar to HCFC-22. The higher saturation level of water in both the refrigerant and lubricant makes the likelihood

of capillary freeze up due to moisture less likely.

CONCLUSIONS

The air conditioning and refrigeration industry is undergoing tremendous change. The contractors who work in this industry are not exempt from change. In order to survive as individual companies and as a prosperous industry group, they must seek sources of competitive advantage. One source of such an advantage lies in understanding the basic facts surrounding the many new products that are being offered by their suppliers. This understanding allows them to provide confident guidance to their ultimate customers who must pay for many of the improvements that are brought about by the technological changes.

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